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The Influence of Time of Harvest and Age of Sixteen Sugarcane Varieties on their Sucrose Content

G. Samuels, S. Alers-Alers, and P. Landrau, Jr.[1]

INTRODUCTION

It is customary in Puerto Rico to harvest sugarcane during a 6-month period extending from January to June. The sugarcane harvested falls into two age groups—1, a fall-plant cane (gran cultura) aged from 14 to 18 months; and 2, spring-plant cane (primavera) and ratoons aged 12 months. The grinding season is normally begun with the older fall-plant canes in January and February. During the major portion of the grinding season from March to June ratoon and spring-planted cane is used.

From experience both the grower and the sugarcane mill are aware of the influence of the time of the year the cane is ground on its sucrose content. The records of the sugarcane factories regularly show that the highest average sucrose for the grinding season occurs in the latter part of March and during April.

Variations are encountered from one year to the next in the sucrose content of sugarcane. The effects of weather and climate on the sucrose content of sugarcane for Puerto Rico have been investigated and discussed by Lugo-López and Capó (*2*)[2]. However, very little published information is available on the variation of the sucrose content of sugarcane throughout the year in Puerto Rico. Fernández-García (*1*) reported in 1928 on experiments carried out in Río Piedras at the Experiment Station on the influence of fertilizers on the quality of sugarcane. The work revealed little influence of the fertilizers used on cane-juice quality. However, the variation of sucrose in the monthly cane samplings from November to June revealed that the highest sucrose values occurred March 14–18, and only slightly lower values April 18–22.

Lugo-López, Samuels, and Méndez (*3*) investigated the influence of varieties on the sucrose content of sugarcane. However, they did not report

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[2] Italic numbers in parentheses refer to Literature Cited, p. 10.

the variation in sucrose content for different varieties throughout the harvest season.

The grower and the factory are both faced with a problem of trying to maintain the sucrose content of the sugarcane harvested at the highest levels possible. Knowing from experience that, in the beginning and the end of the grinding season sucrose values in general are lower, they seek to raise these values by using sugarcane varieties to grind in those months the sucrose values of which are high. The classification of such sugarcane varieties suitable for early or late harvesting is normally determined from experience.

It is the purpose of this paper to report the influence of the time of harvest and age of cane at harvest on the sucrose content of 16 sugarcane varieties, and to show differences in varietal performance attributable to these factors which can be used to rank these varieties as early-, intermediate-, or late-maturing canes.

PROCEDURE

The experiment concerned 16 sugarcane varieties planted at the same time and harvested from an age of 6 months after planting and, thereafter, every 15 days until an age of 23 months. The experiment was planted at the Solís Farm of the Agricultural Experiment Station, University of Puerto Rico, Río Piedras. The soil used was a Vega Alta clay, a highly leached soil. It has a friable brown heavy-clay surface soil about 8 inches thick, underlain by a reddish-brown, heavy, slightly plastic clay about 10 or 12 inches thick.

The 16 cane varieties used were: P.R. 902, P.R. 903, P.R. 905, P.R. 968, P.R. 969, P.R. 975, P.R. 980, P.R. 999, P.R. 1000, M. 336, B. 37161, B. 41227, B. 37172, C.A. 38102, C.A. 3874, and H. 328560. The P.R. varieties were developed at the Agricultural Experiment Station, University of Puerto Rico, Río Piedras; the M. 336 at the Federal Experiment Station of the United States Department of Agriculture at Mayagüez, P. R.; the B. varieties in Barbados, B.W.I.; the C.A. varieties at Central Aguirre, Aguirre; and the H. 328560 at the Hawaiian Sugar Planters' Association Experiment Station, Hawaii.

The varieties were planted on plots consisting of 22 rows 4½ feet apart, or an area of 2,376 square feet or one-eighteenth of an acre. Twenty-five three-eyed sugarcane seed pieces were placed in the bottom of each furrow and covered with soil. This gives a planting rate of about 10,000 sugarcane seed pieces per acre.

The planting took place on June 22, 1954, and was fertilized on June 29 with a 14-4-10 fertilizer at the rate of 1,500 pounds per acre. The first cutting for each variety was made on December 22, 1954, when the varieties were 6 months old. Cuttings were then made every 15 days thereafter.

Although the 16 sugarcane varieties were planted without replication,

each variety had 22 rows in its plot. One row from each variety plot was cut at each harvesting date. Each variety plot was fully randomized for the choice of row within each plot to be harvested. The production from each row was weighed at time of harvest. Ten whole canes were selected at random from each harvested row for sucrose determination. The samples were ground and analyzed for sucrose-percent-cane as described in a previous publication (*4*).

RESULTS

The results of all 16 varieties grouped together are given in table 1 and in figure 1. The sucrose-percent-cane had two maximum peaks, both in April: one at 10.2 months of age, April 27, 1955 and the other at 21.6 months of age, April 12, 1956. Low sucrose values were obtained with the first cuttings at 6 to 7 months and, in the August-September period, at an age of 14 months.

The tons of cane produced per acre increased with increasing age of the cane until about 18 months when it began to drop off. From a maximum of 51 tons per acre at 17.5 months, the mean of the 16 sugarcane varieties began to decrease as the cane grew older to a minimum of 37 tons at 23 months. This decrease of 14 tons was due mainly to dead canes and some minor rat damage.

As shown in table 1, maximum yields of 96° available sugar per acre for the mean of the 16 varieties were achieved at 18.5 months of age.

The individual varieties displayed quite a variation in yields of sucrose and cane tonnage. As shown in table 2, the average sucrose-percent-cane was highest for M. 336 and lowest for P.R. 999. For average tons of cane per acre, B. 41227 was first with P.R. 980 and C.A. 38102 tied for second place, and B. 37161 and P.R. 903 last. In terms of 96° available sugar per acre C.A. 38102 was first, P.R. 980 second, and P.R. 903 last.

The individual varieties displayed marked differences in the time of the year they had their peaks and lows of sucrose-percent-cane. Although the average high for 6- to 12-month cane was on April 27 with 12.08 sucrose-percent-cane, some varieties reached their peak weeks before or after this date. The variations in highest sucrose-percent-cane for the 16 varieties are given in table 3. Here we see that P.R. 902 hit its peak on February 8 with 13.96 and M. 336 on February 23 with 15.90. M. 336 has long been favored by the growers and mills to begin the harvest season in January because of its high sucrose content at this early date. For the 18- to 23-month cane, M. 336 was first with a high of 15.69 sucrose-percent-cane when the average for all 16 varieties for this age group was 12.18 percent on April 12. C.A. 3874, C.A. 38102, and P.R. 999 all had their highest sucrose contents in January for 18- to 23-month cane.

Some sugarcane varieties have their highest sucrose content after the

TABLE 1.—*The influence of time of cutting and age of cane on the mean yields of 16 sugarcane varieties*

Cutting No.	Date of cutting	Age of cane when cut	Mean yields per acre for—		
			Sucrose in cane	Cane	96° available sugar
		Months	*Percent*	*Tons*	*Cwt.*
1	Dec. 22, 1954	6.0	8.27	12	19.4
2	Jan. 7, 1955	6.5	7.64	15	22.6
3	Jan. 22, 1955	7.0	8.45	14	23.3
4	Feb. 8, 1955	7.6	10.20	14	30.0
5	Feb. 23, 1955	8.0	10.48	18	39.4
6	Mar. 14, 1955	8.7	11.07	15	34.6
7	Mar. 28, 1955	9.3	11.21	20	45.6
8	Apr. 12, 1955	9.5	11.89	21	50.6
9	Apr. 27, 1955	10.2	12.08	23	55.8
10	May 12, 1955	10.7	11.42	24	55.7
11	May 27, 1955	11.2	11.05	28	61.9
12	June 10, 1955	11.6	10.62	29	60.2
13	June 24, 1955	12.0	10.05	30	59.8
14	July 11, 1955	12.1	9.63	34	65.9
15	July 28, 1955	13.2	9.96	36	70.4
16	Aug. 12, 1955	13.7	10.38	37	73.3
17	Aug. 27, 1955	14.2	9.30	35	65.2
18	Sept. 12, 1955	14.7	9.34	39	70.3
19	Sept. 27, 1955	15.2	9.49	40	74.5
20	Oct. 11, 1955	15.6	9.57	40	77.7
21	Oct. 25, 1955	16.1	9.66	45	86.8
22	Nov. 8, 1955	16.5	10.02	49	97.2
23	Nov. 22, 1955	17.0	9.57	41	79.6
24	Dec. 6, 1955	17.5	10.16	51	101.6
25	Dec. 20, 1955	18.0	10.60	42	90.7
26	Jan. 4, 1956	18.5	11.38	49	112.3
27	Jan. 17, 1956	18.9	11.33	44	98.8
28	Jan. 31, 1956	19.4	10.93	47	103.5
29	Feb. 14, 1956	19.9	11.38	38	86.0
30	Feb. 28, 1956	20.3	11.17	44	101.6
31	Mar. 13, 1956	20.6	12.01	38	91.6
32	Mar. 28, 1956	21.1	11.62	42	98.3
33	Apr. 12, 1956	21.6	12.18	37	91.8
34	Apr. 26, 1956	22.1	11.61	32	72.4
35	May 11, 1956	22.6	11.33	42	95.3
36	May 26, 1956	23.1	11.21	37	82.7

April peak. We see in table 3 that P.R. 968 reached its peak content of 12.37 sucrose-percent-cane on June 12 for cane aged 6 to 12 months. B. 37161, P.R. 905, and P.R. 980 all reached their peaks on May 12. For 18- to 23-month cane, P.R. 903 and P.R. 968 reached their high points on May 11, about 1 month later than the average high of April 12.

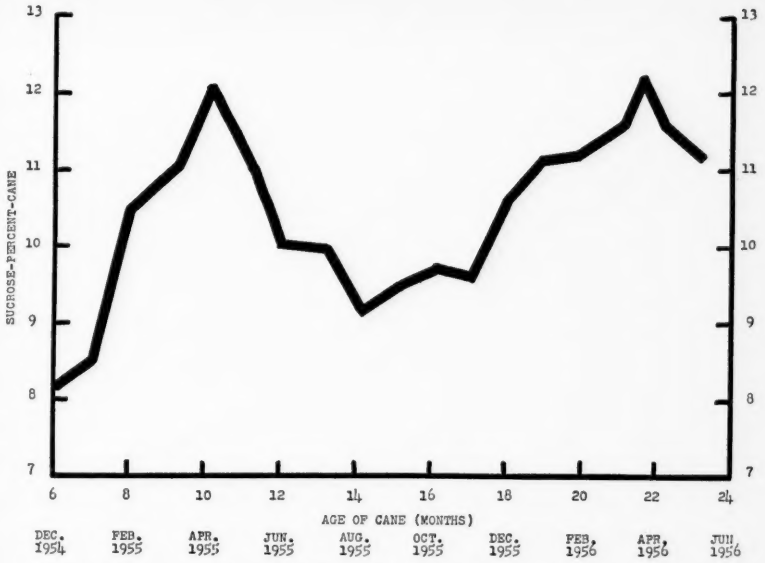

FIG. 1.—Influence of time of year cane is harvested on its sucrose-percent-cane content for the mean of 16 sugarcane varieties.

TABLE 2.—*The average yield of sucrose-percent-cane, cane per acre, and 96° available sugar per acre by 16 sugarcane varieties*

Variety	Sucrose in cane	Cane per acre	96° available sugar per acre
	Percent	*Tons*	*Cwt.*
B. 37161	10.69	24	51.3
B. 37172	10.41	39	81.2
B. 41227	9.92	44	87.3
C.A. 3874	10.99	36	79.1
C.A. 38102	11.25	42	94.5
H. 328560	10.32	28	57.8
M. 336	12.41	32	79.4
P.R. 902	11.57	30	69.4
P.R. 903	10.13	24	48.6
P.R. 905	10.78	32	69.0
P.R. 968	10.21	29	59.2
P.R. 969	10.55	32	67.5
P.R. 975	10.62	29	61.6
P.R. 980	10.63	42	89.3
P.R. 999	9.31	34	63.3
P.R. 1000	9.75	38	74.1

A ranking of the varieties as to when they reached their maximum sucrose-percent-cane content or maturity is given in table 4. We consider all varieties cited at the top of the table for January and February as suitable for early harvesting or early maturing. Those at the end of the table for May and June are regarded as late-harvesting varieties, or late-maturing.

TABLE 3.—*The highest and lowest sucrose-percent-cane values of 16 sugarcane varieties harvested from December 22, 1954 to May 26, 1956*

Variety	Highest sucrose-percent-cane content of cane 6–12 months old			Highest sucrose-percent-cane content of cane 18–23 months old			Lowest sucrose-percent-cane content of cane 12–18 months old	
	Date	Amount	Period with change less than 1 percent	Date	Amount	Period with change less than 1 percent	Date	Amount
		Percent	*Weeks*		*Percent*	*Weeks*		*Percent*
B. 37161	May 12	12.49	2	Apr. 12	12.99	16	July 11	8.50
B. 37172	Apr. 27	13.02	6	Mar. 28	13.16	2	Oct. 11	7.75
B. 41227	Apr. 27	13.11	4	Apr. 12	12.17	4	Aug. 27	7.86
C.A. 3874	Apr. 27	12.03	6	Jan. 4	12.97	4	July 28	8.90
C.A. 38102	Apr. 12	12.86	4	Jan. 17	13.38	2	Aug. 27	7.94
H. 328560	Apr. 12	12.31	10	Feb. 14	12.31	2	Oct. 25	8.85
M. 336	Feb. 23	15.90	2	Jan. 4	15.69	2	Sept. 27	9.80
P.R. 902	Feb. 8	13.96	2	Apr. 12	13.69	2	Nov. 22	8.64
P.R. 903	Apr. 27	11.64	8	May 11	12.96	4	Nov. 22	8.22
P.R. 905	May 12	13.96	10	Apr. 27	13.26	4	Nov. 22	6.99
P.R. 968	June 12	12.37	2	May 11	12.47	8	Oct. 25	8.18
P.R. 969	Apr. 12	11.40	2	Feb. 28	12.61	10	June 10	7.57
P.R. 975	Apr. 12	12.66	4	Apr. 12	13.02	4	Nov. 22	8.13
P.R. 980	May 12	13.20	2	Apr. 27	13.14	14	Aug. 12	8.79
P.R. 999	Apr. 12	12.13	6	Jan. 17	12.28	2	June 24	6.59
P.R. 1000	Apr. 27	12.16	2	Apr. 12	12.57	2	Dec. 6	7.63
Average of varieties	Apr. 27	12.08	12	Apr. 12	12.18	16	Aug. 27	9.30

Of interest to both the grower and the factory is not only when a variety reaches its peak sucrose content, but also how long this peak is maintained. Using as a criterion a loss of less than 1 percent in sucrose-percent-cane, the number of weeks each variety held its peak of sucrose is given in table 3. We see that, for a period of 10 weeks, H. 328560 and P.R. 905 did not drop more than 1 percent of sucrose from their peaks, whereas, M. 336 maintained its high of 15.90 for only 2 weeks for cane of 6 to 12 months of age before it dropped to less than 14.90. When we consider cane 18 to 23 months of age, B. 37161 did not show a loss of more than 1 percent for 16

weeks and P.R. 980 for 14 weeks. The 18- to 23-month-old canes tended to hold their high sucrose values over a longer period than did the 6- to 12-month canes. As shown at the bottom of table 3, the 18- to 23-month-old canes held their high sucrose level for an average of 16 weeks as compared with 12 weeks for the 6- to 12-month-old sugarcane.

TABLE 4.—*The ranking of 16 sugarcane varieties by date as to when they reached their highest sucrose-percent-cane content at time of harvest*

Highest sucrose-percent-cane content of cane 6–12 months old		Highest sucrose-percent-cane content of cane 18–23 months old	
Date	Variety	Date	Variety
Feb. 8	P.R. 902	Jan. 4	C.A. 3874
			M. 336
Feb. 23	M. 336	Jan. 17	C.A. 38102
			P.R. 999
Apr. 12	C.A. 38102		
	H. 328560	Feb. 14	H. 328560
	P.R. 969		
	P.R. 975	Feb. 28	P.R. 969
	P.R. 999		
		Mar. 28	B. 37172
Apr. 27[1]	B. 37172		
	B. 41227	Apr. 12[1]	B. 37161
	C.A. 3874		B. 41227
	P.R. 903		P.R. 902
	P.R. 1000		P.R. 975
			P.R. 1000
May 12	B. 37161		
	P.R. 905	Apr. 27	P.R. 905
	P.R. 980		P.R. 980
June 12	P.R. 968	May 11	P.R. 903
			P.R. 968

[1] The date when the mean of all 16 varieties tested reached its peak.

The lowest sucrose contents for the varieties between 12- to 18-month-old canes also showed variation. From the average low for 16 varieties of 9.30 sucrose-percent-cane, on August 27, P.R. 969 reached its low on June 10 but P.R. 1000 took until December 6 to reach its lowest point.

SUMMARY

Sixteen sugarcane varieties were planted at the same time at Río Piedras and harvested at 15-day intervals from ages of 6 to 23 months to study the

influence of the time of year and age of cane harvested on the sucrose content of the sugarcane varieties. The varieties used were: P.R. 902, P.R. 903, P.R. 905, P.R. 968, P.R. 969, P.R. 975, P.R. 980, P.R. 999, P.R. 1000, M. 336, B. 37161, B. 37172, B. 41227, C.A. 3874, C.A. 38102, and H. 328560. The results obtained were as follows:

1. The average sucrose-percent-cane content for the 16 varieties reached a peak on April 27, 1955, with a cane age of 10.2 months and a sucrose-percent-cane content of 12.08, and another peak on April 12, 1956, at a cane age of 21.6 months and with a sucrose-percent-cane content of 12.18.

2. The lowest sucrose values for the average of the 16 varieties were obtained with the beginning harvests at 6 to 7 months, and in the August-September period at a cane age of 14 months.

3. The tons of cane per acre for the mean of the 16 varieties increased with increasing cane age until about 18 months when it began to decline.

4. Maximum yields of 96° available sugar for the 16 varieties were reached at a cane age of 18.5 months.

5. The individual varieties displayed a wide variation in sucrose-percent-cane content with the highest values for M. 336 and the lowest for P.R. 999.

6. The individual varieties displayed marked differences in the time of the year they had their peaks and lows of sucrose. P.R. 902 and M. 336 were the earliest maturing varieties of the 6- to 12-month canes, reaching their peaks of sucrose in February, and B. 37161, P.R. 905, and P.R. 980 were late-maturing, reaching their peaks of sucrose in May, with P.R. 968 in June.

7. For canes of 18 to 23 months, C.A. 3874, C. 38102, and P.R. 999 all attained their highest peaks of sucrose in January, and P.R. 903 and P.R. 968 reached theirs in May.

8. The lowest sucrose contents were achieved in a range from June 10 for P.R. 969 to December 6 for P.R. 1000.

9. A ranking of the 16 varieties is presented showing when they reached their maximum sucrose-percent-cane contents or maturity.

10. The number of weeks that the variety changed less than 1 percent in sucrose-percent-cane from its peak value is presented for the 16 varieties. In general, canes 18 to 23 months old maintained their peak for 16 weeks as compared with 12 weeks for the 6- to 12-month-old canes.

RESUMEN

Se sembraron 16 variedades de caña de azúcar al mismo tiempo en Río Piedras, las cuales se cosecharon a intervalos de 15 días, desde la edad de 6 a 23 meses. El objetivo fué estudiar la influencia que tuviera la estación

del año sobre la edad de la caña cosechada y sobre el contenido de sacarosa de las distintas variedades. Las variedades usadas fueron: P.R. 902, P.R. 903, P.R. 905, P.R. 968, P.R. 969, P.R. 975, P.R. 980, P.R. 999, P.R. 1000, M. 336, B. 37161, B. 37172, B. 41227, C.A. 3874, C.A. 38102, y H. 328560. Los resultados obtenidos fueron los siguientes:

1. El porcentaje promedio del contenido de sacarosa en la caña, tomando en consideración las 16 variedades, llegó a su expresión máxima en abril 27 de 1955 en la caña de 10.2 meses, cuyo contenido de sacarosa fue de 12.08 por ciento. También se logró en abril 12 de 1956 en una caña de 21.6 meses, cuyo contenido de sacarosa alcanzó 12.18 por ciento.

2. Los valores más bajos de sacarosa, como promedio de las 16 variedades se obtuvieron, al empezar la cosecha, o sea, entre los 6 y 7 meses y en el período de agosto a septiembre en una caña de 14 meses.

3. Las toneladas de caña producidas por acre, promedio de las 16 variedades, aumentaron según aumentó la edad de la caña hasta llegar a los 18 meses. De ahí empezó a declinar.

4. Los rendimientos máximos de azúcar a 96° para las 16 variedades se obtuvieron cuando la caña tuvo 18.5 meses.

5. Las variedades individuales demostraron una gran variación en el porcentaje del contenido de sacarosa en la caña. Los valores más altos se le acreditaron a la variedad M. 336 y los más bajos a la P.R. 999.

6. Las variedades individuales demostraron diferencias marcadas en la estación del año que lograron su mayor y menor contenido de sacarosa. Las cañas de 6 a 12 meses de las variedades P.R. 902 y M. 336, que fueron las que maduraron más tempranamente, alcanzaron su mayor contenido de sacarosa en la caña en febrero y las de B. 37161, P.R. 905 y P.R. 980 maduraron tardiamente y obtuvieron su mayor contenido de sacarosa en la caña en mayo. La P.R. 968 lo obtuvo en junio.

7. Las cañas de 18 a 23 meses de las variedades C.A. 3874, C. 38102 y P.R. 999 todas lograron su mayor contenido de sacarosa en la caña en enero; la P.R. 903 y la P.R. 968 lo alcanzaron en mayo.

8. Los contenidos más bajos de sacarosa en la caña se obtuvieron desde junio 10 en la P.R. 969 y en diciembre 6 en la P.R. 1000.

9. Una evaluación de las 16 variedades se presentan de acuerdo al período en que éstas llegaron a su máximo porcentaje de contenido de sacarosa o a su madurez.

10. El número de semanas que la variedad se desvió de su mayor porcentaje de contenido de sacarosa, en menos de 1 por ciento, se presenta en cuanto a las 16 variedades. En general, las cañas de 18 a 23 meses mantuvieron su mayor contenido de sacarosa durante 16 semanas, comparadas con sólo 12 semanas para las cañas de 6 a 12 meses.

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Influence of Height of Cane and Leaf Stage at Time of Sampling on Leaf-Nutrient Content of Sugarcane

G. Samuels, P. Landrau, Jr., and S. Alers-Alers[1]

INTRODUCTION

To anyone working on either plant or soil analyses the importance of a representative sample is well-known. It is usually expressed in the saying, "No method of soil or plant analysis is any better than the sample taken". The question often confronts workers using foliar-diagnostic methods as to what cane should be taken in the field at sampling time.

From the side of the road a cane field may appear to the layman as rather uniform in height and growth. Yet this cane field is made up of a rather heterogeneous population as regards cane height and growth. The old or original plant tillers grow side by side with intermediate and young plant tillers. Even when cane heights are about the same to the eye, some canes will have a few more leaves on them than others.

Thus, regardless of the date chosen to sample the leaves of the sugarcane, it is problematical whether your sample is a representative one or is influenced by such factors as cane height or leaf stage. The objective of the work herein reported was to determine whether, at a given time of leaf sampling, the height of the cane or its leaf stage would influence the nutrient content (N-P-K) of the leaf.

PROCEDURE

The leaf material used in this study came from a sugarcane fertilizer experiment described in an earlier paper (*2*)[2]. The plant cane of a planting of B. 41227 and M. 336 grown on a Vega Baja silty clay at the Agricultural Experiment Station at Río Piedras was used. The experiment was planted on June 18, 1954.

Leaf samples for determining the influence of the height of the cane at sampling time on the leaf-nutrient content were taken at a cane age of 3 months from variety B. 41227. Leaf samples were chosen from canes measuring about 12 inches as young tillers, 24 inches as intermediate tillers, and 36 inches as original plant tillers. The measurements were made from the first visible leaf ligule to the soil line. Leaf samples were taken from the various fertilizer plots using the three class measurements for height.

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[2] Italic numbers in parentheses refer to Literature Cited, p. 15.

Both varieties, B. 41227 and M. 336, were used in the study on the influence of the leaf stage on the leaf-nutrient content. Leaf stage was defined herein as the number of fully developed green leaves present on the plant at time of sampling. Numbering began with the first fully developed leaf. The rolled spindle leaf was not counted. Leaf samples were taken at 7, 9, 11, and 13 weeks at respective leaf stages of 6 and 8, 8 and 10, 10 and 12, and 12 and 14 leaves.

The entire leaf was utilized for all leaf samples taken. The procedures for the preparation of the leaf samples and the chemical analyses are given in a previous publication (*1*).

RESULTS

Cane Heights

Variations in the height of the cane in a field being sampled do not seem to have any marked influence on the nitrogen or potassium content of the leaf sample (table 1). The variation in the height of cane at time of sampling influenced leaf-phosphorus values in the no-phosphorus treatment only. There was an increase in leaf-phosphorus values with increase in cane height. In general, it may be said that leaf-nutrient values did not tend to change as the cane height increased, except for phosphorus.

There were significant differences in leaf-nutrient values for each respective element with increased application of that fertilizer element to the soil (table 1).

It appears that variations in cane height at sampling time do not have any marked influence on leaf-nutrient values. Care should be taken, however, to avoid selecting as samples plants that are not truly representative of the field sampled. Possibly short young tillers are more sensitive indicators of phosphorus deficiencies than taller more mature tillers.

Leaf Stage

Except in a few cases the leaf stage, or number of leaves present at time of leaf sampling, involving a simultaneous variation in age of 4 weeks, *i.e.*, from 7 to 11 weeks of age, had no significant influence on the nutrient content of the sugarcane leaf (table 2). When leaf samples were taken at 9 weeks, at a leaf stage of from 8 to 10 leaves, there was a significant difference in nitrogen for M. 336. That is to say cane with only 8 leaves had a significantly lower leaf-nitrogen content than did cane with 10. This was the only sampling which showed differences. Otherwise there were no significant differences in leaf-nitrogen, regardless of leaf stage at time of sampling.

In the 9-week sample, where 8 and 10 leaves were present on the cane, there was a significant difference between leaf-phosphorus values at differ-

TABLE 1.—*The influence of the height of sugarcane at time of leaf sampling on its leaf-nutrient content*

Height of cane (inches)	Leaf-nutrient value on a dry-weight basis for fertilizer treatment level indicated[1]			
	0	1	2	Mean of all levels
	Nitrogen (N)			
	Percent	*Percent*	*Percent*	*Percent*
12	0.99	1.39	1.55	1.31
24	1.17	1.45	1.57	1.40
36	1.15	1.29	1.40	1.28
Mean of all heights[2]	1.10	1.38	1.51	
L.S.D. 5 percent	0.21	0.21	0.21	0.13
L.S.D. 1 percent	.29	.29	.29	.19
	Phosphorus (P)			
12	0.13	0.15	0.18	0.15
24	.16	.15	.18	.16
36	.18	.17	.19	.18
Mean of all heights[2]	.15	.16	.18	
L.S.D. 5 percent	0.024	0.024	0.024	0.017
L.S.D. 1 percent	.033	.033	.033	.024
	Potassium (K)			
12	0.80	1.32	1.46	1.19
24	.74	1.24	1.53	1.17
36	.82	1.41	1.75	1.33
Mean of all heights[2]	.79	1.33	1.58	
L.S.D. 5 percent	0.29	0.29	0.29	0.19
L.S.D. 1 percent	.40	.40	.40	.26

[1] The following quantities of fertilizer in pounds per acre were used for the indicated units.

Fertilizer units	Nitrogen treatments			Phosphorus treatments			Potassium treatments		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
0	0	300	300	300	0	300	300	300	0
1	150	300	300	300	150	300	300	300	150
2	300	300	300	300	300	300	300	300	300

[2] For the comparison of the mean of all heights for the indicated nutrient:

	Nitrogen (N)	Phosphorus (P)	Potassium (K)
L.S.D. 5-percent level	0.12	0.011	0.16
L.S.D. 1-percent level	.16	.015	.22

ent leaf stages. However, the effect of leaf stage is not at all clear because the leaf phosphorus was significantly higher in the 10-leaf stage of B. 41227 than in the 8-leaf one. But the reverse was true of M. 336. No significant influence of leaf stage was found for the other three sampling ages.

No differences in leaf-potassium were found at different leaf stages at any of the times of samplings tried.

TABLE 2.—*The influence of the sugarcane leaf stage at time of leaf sampling on its leaf-nutrient content (percent)*

Leaf stage[1]	Leaf-nutrient value on a dry-weight bas s for element indicated—					
	Nitrogen (N)		Phosphorus (P)		Potassium (K)	
	B. 41227	M. 336	B. 41227	M. 336	B. 41227	M. 336
6	2.20	2.29	0.22	0.22	1.34	1.48
8	2.15	2.35	.22	.22	1.40	1.55
L.S.D. 5 percent	.137	.119	.016	.017	.114	.114
L.S.D. 1 percent	.187	.163	.022	.023	.156	.156
8	1.69	1.57	.19	.20	1.60	1.71
10	1.71	1.75	.23	.18	1.68	1.80
L.S.D. 5 percent	.100	.131	.013	.013	.185	.196
L.S.D. 1 percent	.136	.179	.018	.018	.252	.267
10	1.33	1.33	.19	.19	1.51	1.57
12	1.30	1.32	.20	.19	1.41	1.60
L.S.D. 5 percent	.086	.081	.013	.010	.178	.113
L.S.D. 1 percent	.118	.110	.018	.013	.242	.154
12	1.18	1.36	.19	.20	1.34	1.80
14	1.20	1.36	.18	.20	1.40	1.77
L.S.D. 5 percent	.091	.088	.011	.014	.158	.138
L.S.D. 1 percent	.125	.120	.015	.019	.215	.188

[1] The 6–8 leaf stage was sampled 7 weeks after the cane was planted, the 8–10 leaf stage 9, the 10–12 leaf stage 11, and the 12–14 leaf stage at 13 weeks.

There was a general decrease in leaf-nutrient content as the age of the leaf sample increased in the various leaf stages. This decrease of leaf-nutrient content with age had been previously found to be true in general for sugarcane, as reported in detail in a previous publication (*3*).

For practical purposes it appears that no special consideration need be given to the leaf stage at time of leaf sampling. This is especially true for leaf sampling at such an early age as 3 months, as recommended for use in Puerto Rico (*1*). As can be seen from table 2, leaf samples taken at 13 weeks, with a leaf stage of 12 to 14 leaves, showed no significant variation in leaf-nutrient content with leaf stage.

SUMMARY

Leaf samples of sugarcane were taken from a fertilizer experiment at Río Piedras with varieties B. 41227 and M. 336 to determine whether the height of cane or the number of leaves present at leaf-sampling time influenced the nutrient content of the leaf sample. It was found that:

1. There was no significant difference in leaf nitrogen or potassium from cane tillers aged 3 months with heights of 12, 24, and 36 inches.

2. Variations in cane height at time of sampling did influence leaf-phosphorus values; there were increases in cane height.

3. The number of leaves present at time of sampling (7–13 weeks) did not influence leaf-nutrient values in general, except for nitrogen and phosphorus at 9 weeks of age. Here the trends of this influence with the two varieties studied were contrary.

RESUMEN

Se tomaron muestras de hojas de caña de azúcar de un experimento sobre abonos llevado a cabo en Río Piedras con las variedades B. 41227 y M. 336 para determinar si la altura de la caña o el número de hojas presente, al tiempo de tomar las muestras, influía sobre el contenido de nutrientes en la hoja. Los resultados demostraron lo siguiente:

1. En una caña de 3 meses no hubo diferencia significativa en el contenido de nitrógeno o de potasa en la hoja de los tallos a las alturas de 12, 24 y 36 pulgadas.

2. En cuanto al contenido de fósforo, las variaciones en la altura de la caña, al tiempo de tomar las muestras, influyó sobre los valores de este elemento en la hoja, aumentándose el fósforo según era mayor la altura de la caña.

3. El número de hojas presente, al tiempo de la toma de las muestras, no influyó, en términos generales, sobre los valores de los nutrientes en la hoja, con excepción del nitrógeno y el fósforo a la edad de 9 semanas. En el último caso, la tendencia de esta influencia en las dos variedades que se estudiaron estuvo en relación opuesta.

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Effects of Potassium Chloride and Sulfate on Pineapple Yields and Quality

George Samuels and Hector Gandía Díaz[1]

INTRODUCTION

In most pineapple-growing areas in the world potassium sulfate is used as the potash source in fertilizing pineapples. Although potassium chloride is usually available to the pineapple grower at a few dollars less per ton than potassium sulfate, it is not preferred. This preference for the sulfate over the chloride is not entirely without foundation. Experiments as early as 1899, by Rolfs in Florida (*5*)[2] showed that the use of potassium sulfate gave higher yields of pineapples when compared with potassium chloride or Kainit[3]. Johansen in Natal (*3*), in 1911, found sulfate of potash and wood-ash gave good results, while chloride of potash produced a white color in the pulp.

In Puerto Rico, there appears to be no previous experimentation to serve as a basis for the choice of the sulfate over the chloride of potassium. Hendricksen (*2*), who did much of the early research work on pineapples in Puerto Rico in the 1920's, stated that potassium sulfate was preferable to potassium nitrate or potassium chloride for pineapples, but failed to cite the reason for his choice.

Although potassium sulfate has been the choice of pineapple growers in Puerto Rico for almost 50 years, there has been no actual local experimental basis for this choice. The preference of the sulfate over the chloride has been based on reports from Florida (*4*) and Hawaii that the chloride produced off-color in the fruit, and lowered yields.

Potassium chloride is used in all fertilizer analyses mixed in Puerto Rico, except those for pineapples and tobacco. If the pineapple grower cared to to use other fertilizer analyses than those especially mixed for pineapple, he would have more flexibility in his pineapple fertilization. However, he must be sure that the potassium chloride in the fertilizer analyses would give as good results as potassium sulfate. Thus, it was the object of this study to determine the differences, if any, in yields and quality of pineapples fertilized with potassium sulfate or potassium chloride under the growing conditions found in Puerto Rico.

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[2] Italic numbers in parentheses refer to Literature Cited, pp. 19–20.

[3] A mineral salt mixture containing potassium sulfate, magnesium sulfate, magnesium chloride, and a small amount of potassium chloride.

PROCEDURES

The experiment was planted on a Bayamón sandy clay at the Pineapple Farm, Manatí, of the Agricultural Experiment Station. The Bayamón sandy clay is found in the large valleys extending from Vega Alta to west of Arecibo. It has a friable brownish-red permeable granular surface soil underlain by a deep-red slightly plastic but permeable clay subsoil. The pH of the surface soil where the experiment was planted was 4.3.

The experiment had two treatments, one in which potassium chloride (60-percent K_2O) was the source of potassium, the second, in which potassium sulfate (50-percent K_2O) was the source of potassium. There were five replications to each treatment arranged in a randomized-block design.

The plots consisted of three 2-row plantings. The distance between the two rows was 2 feet, with 5 feet between each 2-row planting as a passageway. The distance between plants in a row was 16 inches. Two blocks had plots 44 feet long by 21 feet wide, and three had plots 55 feet long by 21 feet wide.

All plots received a total of 300 pounds of nitrogen per acre as ammonium sulfate (20-percent N), and 60 pounds of P_2O_5 per acre as superphosphate (20-percent P_2O_5). For potash, all plots received 240 pounds of K_2O per acre either as potasium chloride or sulfate, depending on the treatment. The fertilizer was placed in two applications.

The experiment was planted on October 10, 1957, with slips from the Red Spanish variety of pineapples, and harvested in six pickings from May 6 to June 17, 1959. Aside from weighing the fruits, representative samples of fruit were taken to the laboratory for testing as to color and chemical composition. The procedures used for these analyses are given in an earlier publication (*1*).

RESULTS

The results of the chloride and the sulfate of potassium on the yields and quality of the Red Spanish pineapple are given in table 1.

Higher yields of both fruit per acre and mean weight of individual fruit were obtained when the sulfate rather than the chloride of potassium was used, an increase of 2.2 more tons of fruit being obtained with potassium sulfate as compared with potassium chloride fertilization. The weight of the individual fruit was also increased from 3.32 pounds with chloride to 3.67 pounds with sulfate of potash.

Not only were there differences in yields due to the two potash sources but the color of the fruit was affected. The pineapples from plants fertilized with potassium chloride were distinctly off from the accepted color for Red Spanish pineapple. The flesh for the chloride-fertilized fruit was white as compared to the yellow found in the sulfate fertilized fruit.

The chemical composition of the fruit, as given in table 1, shows very little difference between the two potash sources as far as its influence on pH, Brix, and invert sugar goes. The titratable acidity of the chloride-treated fruit was lower than that for the sulfate, which gave the former a higher Brix-acid ratio than the latter (see table 1).

DISCUSSION

Thus, it appears that the use of potassium sulfate rather than potassium chloride for pineapples in Puerto Rico is a justifiable practice. As shown by the results, the use of the chloride source of potash reduced yields of pine-

TABLE 1.—*The effect of the chloride and the sulfate of potassium on pineapple yields and quality*[1]

Potassium[2] source	Yield of fruit per acre[3]	Mean weight of individual fruits	Chemical composition of fruit				
			pH	Brix	Invert sugar	Titratable acidity[4]	Brix-acid ratio
	Tons	*Pounds*		*Degree*	*Percent*	*Mgm.*	
Potassium chloride (KCl)	7.0	3.32	4.1	13.4	12.9	463	28.9
Potassium sulfate (K_2SO_4)	9.2	3.67	4.0	13.4	13.1	584	23.0

[1] Least significant differences needed between treatments at: 5-percent level 0.64 (yield of fruit) and 0.249 (mean weight of individual fruits); 1-percent level 1.05 (yield of fruit) and 0.413 (mean weight of individual fruits).

[2] All treatments received 300 lb. N, 60 lb. P_2O_5, and 240 lb. K_2O per acre.

[3] Fruit harvested green for shipping in a total of 6 pickings from May 6, 1959 to June 17, 1959.

[4] Titrated to a pH 8.1 and expressed as milligrams of citric acid per 100 ml. of juice.

apples per acre and also resulted in an unacceptable off-color of the fruit for canning purposes.

It is difficult to say why the sulfate of potassium gives higher yields than does the chloride. The toxicity of the chloride ion itself might be considered the cause. Potassium chloride contains 48 percent of chlorine, so that the 400 pounds of potassium chloride per acre used in the experiment contributed about 190 pounds of chlorine. Leaf samples taken revealed that the chloride-fertilized plants contained 0.61 percent of chlorine on the dry-weight basis as compared to 0.39 percent where potassium sulfate was applied. Sideris and Young (*6*) found that in the presence of adequate potassium, the chloride tolerance of the pineapple plant was high. They found that approximately 1 percent of chlorine (dry-weight basis) in the pineapple leaf did not cause leaf necrosis when potash fertilization was adequate.

Other than the toxic effect of the chloride ion we must consider the beneficial effect of the sulfate ion as a cause for the better yields obtained with potassium sulfate. Potassium sulfate has 55 percent of its weight as the sulfate ion. Cibes and Samuels (*1*) have shown that sulfur deficiency can reduce pineapple yields. Field observations by the authors of commercial harvested fruit in this area revealed visual symptoms similar to those obtained under sulfur deficiency in nutrient culture. The commercial use of ammonium sulfate and superphosphate, both of which contain sulfate sources, serves to complicate the picture. At present not enough information is available as to the sulfate needs or chloride toxicity for pineapples in the Bayamón sandy clay to correctly assess as to which of these two ions is directly responsible for the higher yields.

SUMMARY

An experiment was conducted on a Bayamón sandy clay to determine whether the chloride or the sulfate was the best source of potassium for pineapples. The results were as follows:

1. Pineapples fertilized with potassium sulfate gave a higher yield per acre and a larger mean weight per fruit than those which received potassium chloride.

2. The chloride-fertilized pineapples produced a fruit with off-colored pulp not as acceptable as the standard sulfate-fertilized fruit.

3. The possible roles of the chloride and sulfate ions in pineapple yields are discussed.

RESUMEN

Se llevó a cabo un experimento en un sue lo del tipo Bayamón arenoarcilloso para determinar si era el cloruro o el sulfato la mejor fuente de potasio para la piña.

Los resultados fueron los siguientes:

1. La piña abonada con sulfato de potasa produjo mayores rendimientos por acre y frutas de mayor peso en promedio que la abonada con cloruro de potasa.

2. La piña abonada con cloruro de potasa produjo frutas cuya pulpa no logró su color normal, por lo cual no fueron tan aceptables como las que fueron abonadas con sulfato de potasa.

3. Se presenta una discusión sobre las posibles funciones de los iones del cloruroy del sulfato en cuanto a los rendimientos de la piña.

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Effects of Gibberellic Acid on Dormant Seeds and Subsequent Crops of Pigeonpeas (*Cajanus cajan*)[1]

Raúl Abrams[2]

INTRODUCTION

Pigeonpeas (*Cajanus cajan*) is a legume crop with a high protein content, having an economic farm value in Puerto Rico of over a million dollars per year. Commercially, this is an annual crop in Puerto Rico, hence, from the breeder's standpoint, only one generation can be processed in a given year.

The experiment reported herein was performed to study the possibilities of hastening flowering and reproduction of pigeonpeas with gibberellic acid. Gibberellic acid, one of the gibberillins, has been studied extensively during the past few years by research workers on different crop plants. Reported responses tend to indicate that gibberellic acid stimulates plant growth, yield, breaking of seed dormancy, and early flowering in many crops (*1,2, 3,4,5,6,7*)[3].

From previous work done on other crops it was thought that gibberellic acid might hasten the flowering period of pigeonpeas. This work was therefore initiated to determine the possible usefulness of gibberellic acid in accelerating the breeding work carried on with this crop.

MATERIALS AND METHODS

Seed of the commercial varieties Kaki, Saragateado, and Florido were soaked overnight in solutions containing 0, 20, 30, 40, and 50 p.p.m. of gibberellic acid. All varieties were sown in holes 4 feet apart, four seed per hole, and thinned to one plant per hole. A plot consisted of 10 plants per row, 8 feet between rows, giving a plot size of 40 x 8 feet or about one-hundred-thirty-sixth of an acre.

The experimental design was a split-plot one in which the three commercial varieties were studied in the whole plots. The subplots consisted of the gibberellic acid treatments and the control. All treatments were replicated four times. Data for plant height, days from sowing to flowering, and weight of shelled green peas yielded were recorded.

[1] Contribution from the Isabela Substation.

[2] Assistant Plant Breeder, Agricultural Experiment Station, University of Puerto Rico, Isabela, P. R. The author wishes to express his sincere gratitude to Arturo Riollano, Agronomist in Charge, Isabela Substation, for the suggestion of this problem.

[3] Italic numbers in parentheses refer to Literature Cited, pp. 26–7.

TABLE 1.—*Mean plant height (feet) of pigeonpea plants of varieties Kaki, Saragateado, and Florido, when seed were treated with different levels of gibberellic acid*

Variety	Results of treatment with indicated p.p.m. of gibberellic acid—					Mean
	0	20	30	40	50	
Florido	5.58	5.85	5.29	5.88	5.63	5.65
Kaki	5.72	5.52	5.54	5.47	5.33	5.51
Saragateado	5.19	5.19	5.28	5.40	5.50	5.31
Mean	5.50	5.52	5.37	5.58	5.48	5.49

RESULTS AND DISCUSSION

EFFECT OF GIBBERELLIC ACID ON PLANT HEIGHT OF PIGEONPEAS

Data on the plant heights of pigeonpeas varieties Kaki, Saragateado, and Florido after the seed were treated with different concentrations of gibberellic acid are presented in table 1. The standard errors and least differences for significance between mean plant heights are shown in the following tabulation:

Item	*5-percent level*	*1-percent level*
Varieties:		
Difference between highest and lowest means	0.81	1.18
Difference between 2 adjacents	.65	.98
Standard error 1.87 with 6 d.f.		
Gibberellic acid treatments:		
Highest and lowest	.35	.43
Difference between 2nd and lowest	.33	.41
Difference between 3d and lowest	.30	.38
Difference between 4th and lowest	.25	.33
Standard error 0.087 with 36 d.f.		
Between gibberellic acid treatment for same variety:		
Highest and lowest	.62	.76
Difference between 2nd and lowest	.58	.72
Difference between 3d and lowest	.53	.67
Difference between 4th and lowest	.44	.59
Standard error 0.152 with 36 d.f.		
Between any 2 varieties for same gibberellic acid treatment:		
Highest and lowest	.93	1.30
Difference between 2 adjacents	.81	1.10
Standard error 0.230		

Previous studies on the response of different crops (*1,3,4,5*) had shown that the chemical was capable of promoting growth, *i.e.*, a rapid elongation of shoots and leaves. The results with pigeonpeas showed that treating the seed with different levels of gibberellic acid did not improve the rate of

growth of this crop. No significant differences in plant heights were found between the three commercial varieties used in this trial. A lightening of the green color of the leaves was observed in all varieties treated with 50 p.p.m. of gibberellic acid. The average plant heights for Florido, Kaki, and Saragateado varieties were 5.65, 5.51, and 5.31 feet, respectively. This is in accordance with field observations in commercial and experimental work with these varieties.

Average Number of Days to Flower

The results on the mean number of days taken from sowing to flowering are presented in table 2 and figure 1.

The standard errors and least differences for significance between mean number of days from sowing to flowering are shown in the following tabulation:

Item	*5-percent level*	*1-percent level*
Varieties:		
Difference between highest and lowest means	14.13	20.57
Difference between 2 adjacents	11.26	17.06
Standard error 3.255 with 6 d. f.		
Gibberellic acid treatments:		
Highest and lowest	6.09	7.45
Difference between 2nd and lowest	5.70	7.09
Difference between 3d and lowest	5.18	6.58
Difference between 4th and lowest	4.29	5.76
Standard error 1.496 with 36 d. f.		
Between gibberellic acid treatment for same variety:		
Highest and lowest	10.54	12.90
Difference between 2nd and lowest	9.87	12.28
Difference between 3d and lowest	8.96	11.40
Difference between 4th and lowest	7.43	9.97
Standard error 2.590 with 36 d. f.		
Between any 2 varieties for same gibberellic acid treatment:		
Highest and lowest	16.14	22.66
Difference between 2 adjacents	14.07	19.10
Standard error 3.996		

Table 2 shows that there were highly significant differences in the flowering date between the three pigeonpea commercial varieties. The variety Saragateado flowered significantly later than either Florido or Kaki. This difference agrees consistently with field observations on these varieties during recent years, *i. e.*, Saragateado usually takes from 30 to 45 more days to flower than either Florido or Kaki, and Florido a few days more than Kaki.

None of the gibberellic acid treatments had any significant effect on the number of days to flower of the three pigeonpea varieties. The mean number

TABLE 2.—*Mean number of days from sowing to flowering of pigeonpea varieties Saragateado, Florido, and Kaki when seed were treated with different levels of gibberellic acid*

Variety	Results of treatment with indicated p.p.m. of gibberellic acid—					Mean
	0	20	30	40	50	
Saragateado	161.54	162.97	158.04	158.90	158.82	160.05
Florido	134.97	136.05	135.30	136.64	138.11	136.22
Kaki	124.21	127.71	124.89	128.88	124.96	126.13
Mean	140.24	142.24	139.41	141.47	140.63	140.80

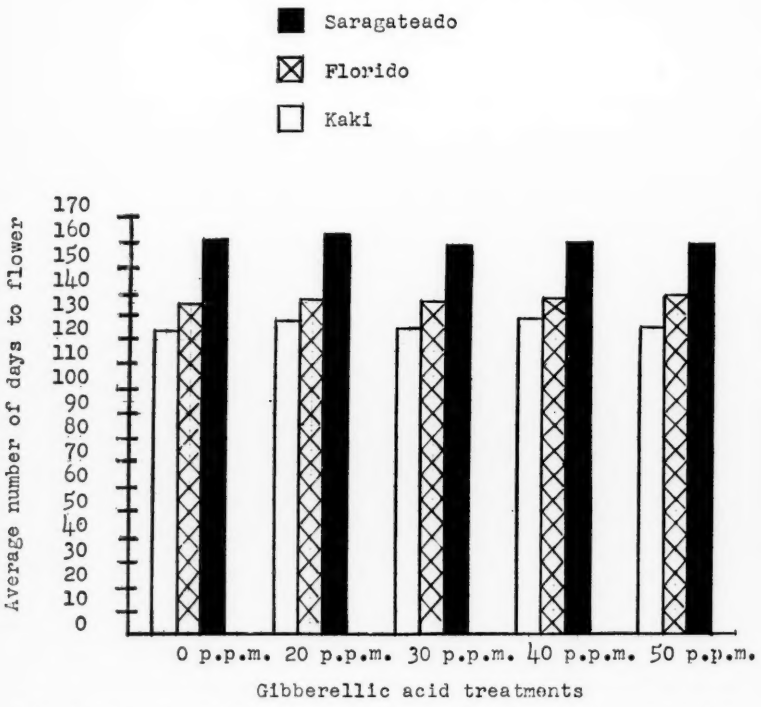

FIG. 1.—Average number of days from sowing to flowering of pigeonpea varieties Saragateado, Kaki, and Florido treated with 0, 20, 30, 40, and 50 p.p.m. of gibberellic acid.

of days from sowing to flowering for the 0, 20, 30, 40, and 50 p.p.m. of gibberellic acid treatments were 140.24, 142.24, 139.41, 141.47, and 140.63, respectively. This is presented graphically in figure 1, the dark column representing the late variety, Saragateado.

Yield Data

The results on the average green weights of shelled peas of varieties Kaki, Saragateado, and Florido, the seed of which were treated with different levels of gibberellic acid, are presented in table 3.

TABLE 3.—*Yield, in pounds per plot of shelled green peas of pigeonpea varieties Kaki, Saragateado, and Florido, when seed were treated with different levels of gibberellic acid*

Variety	Results of treatment with indicated p.p.m. of gibberellic acid—					Mean
	0	20	30	40	50	
Kaki	4.88	5.66	6.30	5.42	6.08	5.66
Saragateado	3.61	2.58	3.44	4.28	3.62	3.51
Florido	.66	.70	.91	.66	.73	.73
Mean	3.05	2.98	3.55	3.45	3.48	3.30

The standard errors and least differences for significance between mean green weights of shelled peas are shown in the following tabulation:

Item	*5-percent level*	*1-percent level*
Varieties:		
Difference between highest and lowest means	3.86	5.62
Difference between 2 adjacents	3.07	4.66
Standard error 0.889 with 6 d. f.		
Gibberellic acid treatments:		
Highest and lowest	1.10	1.34
Difference between 2nd and lowest	1.03	1.28
Difference between 3d and lowest	.93	1.19
Difference between 4th and lowest	.77	1.04
Standard error 0.270 with 36 d. f.		
Between gibberellic acid treatment for same variety:		
Highest and lowest	1.91	2.34
Difference between 2nd and lowest	1.79	2.22
Difference between 3d and lowest	1.62	2.06
Difference between 4th and lowest	1.35	1.81
Standard error 0.469 with 36 d. f.		
Between any 2 varieties for same gibberellic acid treatment:		
Highest and lowest	4.12	5.89
Difference between 2 adjacents	3.62	4.92
Standard error 0.986		

These results show significant differences in yield between varieties, the Kaki variety leading, followed by Saragateado and Florido. There were no significant differences in yield between Saragateado and Florido. Once more these results follow the pattern of production obtained in commercial and experimental work throughout the Island, *i.e.*, the Kaki variety yields best, followed by Saragateado and Florido.

There was no significant difference in yield between the gibberellic acid treatments. The mean average yields for the 0, 20, 30, 40, and 50 p.p.m. gibberellic acid treatments were as follows: 3.05, 2.98, 3.55, 3.45, and 3.48 pounds per plot, respectively.

SUMMARY

Seed of the commercial pigeonpea varieties Kaki, Saragateado, and Florido were soaked overnight in solutions of gibberellic acid containing 0, 20, 30, 40, and 50 p.p.m., in order to determine the effect of the acid on plant height, flowering period, and yield of this crop. The following results were obtained:

1. There were no significant differences in plant height between the three commercial varieties that could be attributed to the gibberellic acid treatments.

2. Varieties differed in their flowering periods, but this could not be attributed to the gibberellic acid treatments, as such differences are of genetic origin.

3. Gibberellic acid had no effect on the yield of green peas.

RESUMEN

Semillas de las variedades comerciales de gandur Kaki, Saragateado y Florido se sumergieron por 12 horas en las siguientes soluciones de ácido giberélico: 0, 20, 30, 40, y 50 partes por millón. Se observaron los efectos de estos tratamientos en relación con la altura de las plantas, número de días hasta la florecida y rendimiento en grano verde. Los resultados fueron como sigue:

1. No se encontraron diferencias en la altura de las plantas debidas a los tratamientos con ácido giberélico.

2. Hubo diferencias significativas entre las variedades en su época de florecida, pero estas diferencias no fueron causadas por los tratamientos de ácido giberélico. Las diferencias fueron de naturaleza genética.

3. El ácido giberélico no causó cambios en cuanto a los rendimientos en grano verde de las variedades estudiadas.

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Phoma Canker of Pigeonpeas in Puerto Rico

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INTRODUCTION

Pigeonpea production in Puerto Rico is quite important in the hilly areas in the vicinities of Peñuelas, Adjuntas, Villalba, and Jayuya. The types of soils and climatic conditions are not particularly adapted for the economical cultivation of many other farm crops.

Remunerative returns are obtained through the marketing of green peas, dry peas, and canned peas. According to a recent report (*1*)[2] 75 percent of the pigeonpeas produced in Puerto Rico are marketed locally and the surplus is shipped to New York. The pigeonpea plants grow perennially in Puerto Rico and a new crop is harvested every year. The bulk of the harvest occurs during the December to February period.

The variety Kaki comprises 55 percent of the area planted and 17 percent of the land is sown with other varieties. About 44 percent of the total area under cultivation is being sown with mixed-variety seed. Considering the farm value of the pigeonpea crop reported in 1954–55, amounting to $1,050,000, it is important to study the diseases impairing this agricultural crop and find practical methods of control.

EPIDEMIC OF PHOMA CANKER

Early in February of 1954 a serious epidemic of phoma canker was observed causing damage to the pigeonpea crop (*Cajan cajan* (L.) Millsp.) grown commercially in the vicinity of Peñuelas, P. R. The lesions appeared on stems and branches, first as minute blotchy spots of irregular shape and varying from a mere speck to swollen cankerous areas 2 or 3 cm. in length. The lesions entered the bark and spread lengthwise. Some of them girdled the stem and branches causing the death of the parts of the plant above.

Seedlings were attacked early with sootylike spots and, if girdled, they succumbed to the infection. Abundant pycnidia were found on the young sootylike spots. Conidia oozed from these pycnidia when they became wet. The conidia progressed down the stems and branches causing lineal infections. The stems and branches had a striped appearance.

The lesions generally enlarged longitudinally, swelling and breaking open the bark and becoming cankerous with age. The cankerous areas split characteristically showing a rough, ruggose appearance. On the stems, the cankers were more common at the collar area.

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[2] Italic numbers in parentheses refer to Literature Cited, p. 30.

RESULTS OF STUDY

The Causal Agent of Disease

The disease is caused by a species of *Phoma* characterized by the formation of papillate pycnidia of variable size. Isolations were made from diseased spots and the fungus grown on agar. In culture, pycnidia are formed singly or in aggregates in a sort of stroma. The conidia are hyaline, obtuse, and measured in length from 3 to 6.4 μ. with an average of 4 x 1.5. μ. No

Fig. 1.—Characteristic cankers produced on Kaki pigeonpea plants by inoculation.

perfect stage of the fungus was found in the lesions of stem and branch nor in culture plates. Pycnidia were also found on the pods. Conidial infections and contamination were evident in some of the seed peas.

Experimental Work

Experiments in the laboratory and greenhouse showed that young pigeonpea plants (Kaki variety) when inoculated by prickling with a needle using drops of a water suspension of conidia obtained from pure culture, or by spraying the young seedlings with suspensions of conidia, showed necrotic lesions a week later. The characteristic cankers obtained from our inoculations are seen in figure 1.

In our inoculation studies under greenhouse conditions it was found that the *Phoma* sp. isolated was capable of inducing the carbonaceous appearance of the cankers produced without presence of other fungi. Further studies on the biology and ecology of the organism seem advisable.

DISCUSSION

R. Leach and J. Wright (*2*) reported a collar and stem canker of pigeonpeas caused by a species of *Physalospora*: a *Phoma* and a *Macrophoma* pycnidia were shown to be the imperfect form of this fungus. These authors also found a *Diplodia* which they thought was responsible for the carbonaceous appearance of the cankers induced by the *Macrophoma*.

SUMMARY

An epidemic of phoma canker was observed in February 1954, causing considerable damage to the pigeonpea crop, a rather important one in Puerto Rico. This paper reports a study of the causal agent, a species of *Phoma* characterized by the formation of papillate pycnidia of variable size. The disease could be produced in healthy pigeonpea plants by inoculation or by spraying with a water suspension of conidia obtained from a pure culture. Further study is advisable.

RESUMEN

En febrero de 1954 se observó una epidemia de *Phoma* gangrenosa que causó mucho daño a la cosecha de gandures, cultivo de gran importancia en Puerto Rico. Este estudio informa sobre el agente causal de la epidemia, que es una especie indeterminada de *Phoma* la cual se caracteriza por la formación de picnidios papilados de distintos tamaños. La enfermedad pudo trasmitirse a plantas saludables de gandures, por medio de la inoculación o mediante las aspersiones con suspensiones de conidios obtenidos de un cultivo puro. Se recomienda la continuación de los estudios sobre esta enfermedad.

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An Evaluation of Five Pole-Bean Varieties for a Breeding Program

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INTRODUCTION

Snap beans are one of the most popular vegetables consumed in Puerto Rico. Practically all the stringless beans consumed in the Island are imported as canned beans. During the fiscal year of 1957–58 the total importation of canned snap beans amounted to 3,053,335 pounds with a value of $372,910 (*1*)[2]. A very small amount is cultivated during the winter months with seed imported from the United States. We feel there is a need to develop a stringless strain of bean adapted to the conditions of Puerto Rico.

In starting a breeding program with the purpose of developing a stringless strain of bean the initial phase consists of assembling and evaluating as well as possible the best currently available material. A knowledge of productiveness, quality, flavor, and disease and insect resistance is needed before selecting the material to be used in our program. To obtain some of this information a bean-variety trial was conducted.

MATERIALS AND METHODS

The five pole-bean varieties used in this trial are planted commercially in the United States. They are characterized by good yield, excellent quality, and processing appearance and flavor. A brief description of the varieties is as follows (*2*):

Kentucky 191 is a leading variety for shipping and for the local market, also for home gardens. The plants are vigorous, productive, and resistant to some strains of rust. The pods are long, smooth, oval, and medium dark-green. The seed are white.

Florigreen is a new variety in the Kentucky 191 class. The plants are vigorous, very productive, and early-maturing. Florigreen is resistant to common bean and southern bean mosaics and also has shown resistance to bean rust. The pods are long, wide, thick, flat, and somewhat rough. The seed are white.

Blue Lake 92 is an early strain in the stringless Blue Lake class. The plant is resistant to common bean mosaic and some strains of bean rust. The pods are very dark-green, round, straight, meaty, and stringless at all stages, and slow in seed development. The seed are white.

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[2] Italic numbers in parentheses refer to Literature Cited, p. 34.

Blue Lake 228 is a strain used for early picking. The plants are vigorous, productive, and resistant to common bean and southern bean mosaics. The variety also has resistance to some strains of bean rust. The pods are nearly straight, round, meaty, medium dark-green, and stringless at all stages. The seed are white.

Blue Lake 231 is a standard variety for a main crop. The plants are vigorous and very productive and resistant to common bean mosaic and some strains of bean rust. The pods are very dark-green, straight, fleshy, nearly round, and stringless at all stages. The seed are white[3].

TABLE 1.—*Harvesting dates and maturity at harvest of 5 pole-bean varieties planted at the Isabela Substation, April 21, 1959*

Variety	Harvest dates	Days of maturity at first harvest
Blue Lake 231	June 10, 16, 23, 26, July 2	61
Florigreen	June 8, 16, 23, 26, July 2	59
Blue Lake 92	June 10, 16, 23, 26, July 2	61
Kentucky 191	June 8, 16, 23, 26, July 2	59
Blue Lake 228	June 10, 16, 23, 26, July 2	61

TABLE 2.—*Total and mean yields of 5-pole-bean varieties planted at the Isabela Substation, April 21, 1959*

Treatments	Total yield per plot	Mean yields per plot	Calculated production per acre
	Pounds	*Pounds*	*Tons*
Blue Lake 231	59.85	11.97	8.14
Florigreen	51.00	10.20	6.93
Blue Lake 92	42.20	8.44	5.74
Kentucky 191	37.50	7.50	5.09
Blue Lake 228	36.35	7.27	4.94

The experiment was planted at the Isabela Substation on April 21, 1959, and the experimental design used was a 5 x 5 latin square. Each plot consisted of two rows, 4 feet apart and 20 feet long, making a plot size of one two-hundred and seventy-second of an acre. In each row 10 hills were planted 2 feet apart, with 2 plants per hill. A 9-10-5 fertilizer at 800 pounds per acre was applied to the planting.

The pods were harvested at the best edible and marketable stage. A total of five pickings was made of each variety.

[3] The seed were obtained from Associated Seed Growers, Inc., New Haven, Conn.

EXPERIMENTAL RESULTS AND DISCUSSION

The results of this trial are presented in tables 1 and 2.

The standard error and least differences required for significance between means in table 2 are shown in the following tabulation:

Item	*5 percent*	*1 percent*
Difference between highest and lowest	4.25	5.51
Difference between highest and 2nd lowest	3.96	5.19
Difference between highest and 3d lowest	3.56	4.75
Difference between highest and 4th lowest	2.91	4.07

The yield of variety Blue Lake 231 was significantly higher at the 5-percent level than the yields of Blue Lake 228 and Kentucky 191. There were no significant differences between the yields of Blue Lake 231 and Blue Lake 92 and Florigreen (*3*). This means that variety Blue Lake 231 proved to be not only good in quality and other desirable characteristics, but also the highest yielding among the pole beans tested. Variety Blue Lake ranks among the best in the State of Oregon, where the average production of pole beans is from 7 to 8 tons per acre. Varieties Blue Lake 231 and Florigreen produced 8.14 and 6.93 tons of beans per acre (*4*), respectively, in this experiment. The yields obtained with varieties Blue Lake 231 and Florigreen compare favorably with the ones obtained in Oregon where yield of beans per acre is generally high. Field observations on this trial showed that variety Kentucky 191 is susceptible to mosaic disease, making it undesirable for our breeding program.

SUMMARY

Of five pole-bean varieties tested Blue Lake 231 and Florigreen are considered to be best suited for use in our proposed snap bean breeding program, both for their good quality and other desirable characteristics, and in the case of Blue Lake 231, also for its superiority in yield to the other pole beans tested. The above varieties produced 8.14 and 6.93 tons of beans per acre, respectively, both of them being highly productive under our conditions. Varieties Blue Lake 92, Kentucky 191, and Blue Lake 228 were also included in the experiments.

RESUMEN

De las cinco variedades de habichuelas trepadoras que se probaron, la variedad Blue Lake 231 fué la mejor, no solamente por su buena calidad, sino también por su superioridad en rendimiento al compararse con las demás variedades. Las producciones de las variedades Blue Lake 231 y Florigreen fueron 8.14 y 6.93 toneladas, respectivamente, lo cual es alto

para cualquier lugar. Las variedades Blue Lake 92, Kentucky 191, y Blue Lake 228 fueron también incluídas en este experimento.

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A Comparison of Ammonium Sulfate and Urea as Tobacco Fertilizers

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INTRODUCTION

Nitrogen is a very important element in the nutrition of tobacco. In Puerto Rico it generally has been supplied for tobacco in the form of ammonium sulfate. In many of the tobacco-growing areas of the United States nitrogen sources other than ammonium sulfate are favored. Connecticut has recommended organic-nitrogen sources such as cottonseed meal, or mixtures of cottonseed meal with urea and ammonium sulfate (*5*)[2], for the production of cigar-wrapper tobacco. Florida found that a combination of nitrogen sources was better than one source alone and obtained highest yields and good quality with a mixture of one-third each of sodium nitrate, urea, and sulfate of ammonia (*2*). Ammonium nitrate was recommended (*4*) for burley tobacco in Tennessee.

Earlier tests with nitrogen sources in Puerto Rico (*3*) showed neither organic sources such as cottonseed meal, nor inorganic sources such as ammonium nitrate, sodium nitrate, or urea superior to ammonium sulfate in producing yields of cigar-filler tobacco. Moreover the yields obtained with urea were definitely inferior to those obtained with ammonium sulfate. Inasmuch as other investigators had reported that urea was equal or superior to ammonium sulfate (*1*), it was decided to reinvestigate the influence of urea and ammonium sulfate as nitrogen sources for cigar-filler tobacco in Puerto Rico. This investigation did not limit the criteria of performance to yields of cured tobacco only, but the influence of these two nitrogen sources on such factors as price, chemical composition, and smoking performance was also determined.

PROCEDURE

The experiment was planted at the Gurabo Substation Farm. The soil used was a Mabí clay, with a pH 5.5. This soil is a grayish-brown plastic heavy clay which drains well on sloping land but very poorly on level ground.

The experiment consisted of three treatments: 1, No nitrogen; 2, ammonium sulfate; and 3, urea. All treatments received 200 pounds each of P_2O_5 and K_2O per acre as superphosphate (20-percent P_2O_5) and potassium sul-

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[2] Italic numbers in parentheses refer to Literature Cited, p. 39.

fate (50-percent K_2O). The nitrogen sources were applied at the rate of 100 pounds of nitrogen per acre.

The plots consisted of 5 rows, 42 inches apart, with 15 tobacco plants 18 inches apart in the row, making a total of 75 plants per plot with an area, 17½ by 22½ feet, or about one one-hundred and eleventh of an acre. Seedlings of tobacco variety Virginia 12 were selected for uniformity in size and development, and were carefully transplanted to the experimental plots. All mosaic-infected plants were discarded. Seedlings were replanted, if needed, 10 days after the first planting. The fertilizer was applied 10 days after planting the tobacco seedlings, being placed in small semicircular bands at opposite sides of the plant and then covered with soil.

The experiment was laid out in a randomized-block design of three treatments with four replications. The experiment was planted on January 2, 1958, and harvested during the month of April 1958. The tobacco leaves were picked every 8 to 10 days after the first picking was made. All plants were pinched back (topped) after they were fully grown, to prevent flowering and induce enlargement of the leaves. The tobacco leaves collected from each plot at each picking were properly identified and hung in racks in the tobacco barn for drying. The dried leaves were classified[3], using the standard grades for Puerto Rican cigar-leaf tobacco (U.S. Type 46), as designated by the Tobacco Division, Agricultural Marketing Service, U. S. Department of Agriculture. The classified air-cured tobacco was then weighed.

The weighed and cured tobacco was fermented and then cigars made from that grown under the various treatments. The fermented stripped tobacco was utilized as cigar-filler and a commercial wrapper-tobacco was used for all treatments in making the cigars.

Cigars were distributed with an appropriate questionnaire to 50 regular cigar smokers to evaluate the smoking qualities of the tobacco from the no-nitrogen, ammonium sulfate, and urea treatments.

RESULTS AND DISCUSSION

The results of the field experiment with ammonium sulfate and urea as nitrogen sources for tobacco are given in table 1. There was no significant difference in yields of field-cured tobacco fertilized with ammonium sulfate or urea. However, yields diminished about 2 hundredweights where no nitrogen was applied, indicating that there was need for nitrogen fertilizers for tobacco on the Mabí clay at Gurabo.

Yields were generally low, even where nitrogen fertilizers were applied; this was attributable, for the most part, to the lack of rainfall, as earlier experiments in this area (*3*) have shown.

[3] The authors wish to thank Mr. Rafael J. González, Tobacco Division, USDA, for classifying the tobacco.

Prices paid for tobacco differ, depending on its quality. A high yield per acre of a poor-quality tobacco may not bring the farmer as much money as an average yield of high-quality tobacco. The reported values of the cured tobacco per acre are based not only on the yields, but also take quality into consideration. The prices paid for tobacco of the quality obtained under the different treatments in the experiment are given in table 1. No statistical difference was found that could be attributed to the treatments.

One hundred pounds of nitrogen as ammonium sulfate applied per acre would have brought the farmer $49.63 more per acre for his tobacco than where no nitrogen was applied. The differences in estimated incomes attributable to urea and to ammonium sulfate were not significant. It should be remembered that in this experiment, sufficient phosphate and potash were

TABLE 1.—*The influence of ammonium sulfate and urea on yields and prices of cured tobacco*

Treatment[1]	Cured tobacco, yield per acre	Cured tobacco	
		Price per acre	Price per pound
	Cwt.	*Dollars*	*Cents*
No nitrogen	3.60	89.97	25
Ammonium sulfate	5.42	139.60	26
Urea	5.71	155.31	27
Least significant differences needed between treatments at the:			
5-percent level	1.25	17.36	

[1] All treatments received 200 lb. each of P_2O_5 and K_2O per acre, and 100 lb. each of N where indicated.

applied, 200 pounds per acre of each, to prevent them from being limiting factors in yields.

To apply 100 pounds of nitrogen per acre required 500 pounds of ammonium sulfate (20-percent N) as compared to 218 pounds of urea (46-percent N). Urea costs more than ammonium sulfate, but since it contains more nitrogen, less than half the weight of fertilizer is required. Urea costs 14.5 cents as compared to 13.7 cents for ammonium sulfate, per pound of nitrogen applied. The saving in warehouse space and cost of application from the use of urea might reduce the slight price edge ammonium sulfate has over it for large acreages of tobacco.

Tobacco is grown in Puerto Rico primarily for cigars. Thus the final means of comparison between these two nitrogen sources used would be in the smoking quality of cigars made from tobacco fertilized with them. In table 2 the results are given of smoking trials with cigars made from

ammonium sulfate- and urea-fertilized tobacco. In general, there was little difference.

Tests in Connecticut have shown that ammonium sulfate fertilization produces a darker ash and a slower burning tobacco than organic-nitrogen sources (*5*). Such quality factors as irritation, aroma of the smoke, taste, and strength of the cigar are unaffected by nitrogen source.

Chemical analyses showed the urea-treated tobacco contained 4.54 percent total nitrogen as compared to 4.80 percent for ammonium sulfate.

TABLE 2.—*Evaluation scores of the smoking characteristics of cigars made from tobacco fertilized with urea and ammonium sulfate*

Treatment	Evaluation score[1] for—						
	Combustibility	Irritation	Aroma of the smoke	Taste of the smoke	Strength of the smoke	Color of ash	Average
No nitrogen	2.7	3.7	3.3	2.7	4.0	3.0	3.2
Ammonium sulfate	3.2	3.8	4.0	3.0	4.0	3.0	3.5
Urea	3.7	4.0	3.9	3.0	4.0	4.4	3.8

[1] The various quality factors were scored as follows:

6 points	Burns well	None	Aromatic	—	Strong	White	Good
4 points	Burns fair	Weak	Plain	Agreeable	Medium	Gray-white	Average
2 points	Burns poorly	Strong	Disagreeable	Disagreeable	Weak	Greyish-black	Poor

The work done by Landrau *et al.* (*3*) indicated that urea gave significantly ower yields of tobacco than did ammonium sulfate. However, this was not the case in the experiment here reported, for no significant differences existed in yields or quality that could be attributed to nitrogen source. While tobacco yields in general were low in this experiment, similar conditions of poor rainfall and low yields were encountered in the former experiments with urea and ammonium sulfate.

From the evidence at hand, it still appears that ammonium sulfate is quite satisfactory as a nitrogen source for growing cigar-filler tobacco in Puerto Rico. Urea might be used, but it offers no economic advantage at present.

SUMMARY

Ammonium sulfate and urea were evaluated as nitrogen sources for growing cigar-filler tobacco in Puerto Rico. The results of an experiment on a Mabí clay at Gurabo were:

1. There were no significant differences in yield between tobacco fertilized with ammonium sulfate and urea.
2. Tobacco grown without nitrogen gave significantly lower yields than that to which nitrogen was applied.
3. The cash value per pound or per acre of cured tobacco did not show any appreciable difference that could be attributed to the two nitrogen sources used.
4. There was little or no differences in the smoking qualities of cigars made from tobacco fertilized with the two nitrogen sources, except for a whiter ash where urea was used.

RESUMEN

En este trabajo se evalúan el sulfato amónico y la urea como fuentes de nitrógeno para el abonamiento del tabaco en Puerto Rico. Los resultados obtenidos mediante la aplicación de estos elementos fertilizantes a un experimento con tabaco llevado a cabo en un suelo del tipo arcilla Mabí en Gurabo fueron los siguientes:

1. No hubo diferencias significativas al comparar los rendimientos del tabaco abonado con sulfato amónico o con urea.
2. Las parcelas a las cuales no se les aplicó abono nitrogenado en forma alguna produjeron rendimientos más bajos, significativamente, que las que recibieron nitrógeno.
3. El ingreso en efectivo por libra o por acre de tabaco vendido, no señaló diferencia alguna que pudiera proceder de la fuente de nitrógeno usada ya fuera sulfato amónico o urea.
4. La diferencia fué poca o ninguna en lo que se refiere a la calidad del tabaco al fumarse y como resultado de su abonamiento con sulfato amónico o con urea. Sólo se observó que la ceniza de los cigarros hechos con el tabaco abonado con urea resultó más blanca.

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Pore Size and Bulk Density as Mechanical Soil Factors Impeding Root Development [1]

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INTRODUCTION

Mechanical impedance can be a factor of considerable importance because of its direct and indirect influences on plant growth (*5*)[3]. Compact soils and subsoils can offer marked resistance to root development. Soil science recognizes genetically developed compacted layers as well as traffic-induced pans (*8*). No really adequate, direct methods have been developed for measuring the work done by roots in penetrating compact soil layers. Thus, measurements of soil properties that might influence root development are generally used. Among them, bulk density and pore size are rather useful yardsticks. This paper reports data on bulk density and pore size for selected profiles where three major uncultivated pasture grasses—Para, Guinea, and Bermuda—were growing. The data are complemented with observations on root development in an attempt to relate the influence of the indicated soil factors on the rooting depth of the grasses.

MATERIALS AND METHODS

The observations and measurements herein reported were done in connection with an extensive study of the major soils of the Lajas Valley in southwestern Puerto Rico (*4*). Data from seven profiles are reported here including the Aguirre, Guánica, Fraternidad, Fe, and Jácana soils. The soils are generally deep, with a strikingly high, almost uniform clay content of the expanding-lattice type, very slow hydraulic conductivity in the subsoil (*3*), and very low aggregate stability below the surface layer (*2*). They are relatively low in organic matter and nitrogen, and generally high in soluble salts and exchangeable sodium, both of which increase with depth. Observations on root development of Para grass, Guinea grass, and Bermuda grass were made in pits 4 feet wide, 4 feet long, and 6 feet deep.

Four undisturbed soil cores were taken from each of the well-defined visible horizons with an Uhland sampler 3 inches in diameter by 3 inches in length. The cores were dried in an oven at 110° C. As the sampler used had a known volume, bulk density was calculated by dividing the net dry weight of the soil by its original volume. The water retained at pF 1.78,

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[3] Italic numbers in parentheses refer to Literature Cited, p. 44.

considered here as an index of the nature of the soil porosity, was measured by bringing the soil cores to equilibrium with a 60-cm. tension and determining the variation in weight of the core.

RESULTS

Measurements of bulk density and porosity are given in table 1 for the selected soils studied where three different uncultivated grasses were growing. Observations on root development are also recorded in table 1.

In an Aguirre soil, profile 2, Para grass roots were abundant in the fluffy, light, topmost 3 inches and then decreased with increases in depth which correlated with increasing percentage by volume of small pores even though bulk-density values were rather low. In profile 19, there was a sharp reduction in root development below the upper 9-inch layer. In this core both high soil density and microporosity are probably at play.

Guinea grass roots developed normally in profile 18, a Fraternidad soil, at densities ranging from 1.15 to 1.39 gm./cc. with over 60 percent of small pores. This grass is rather deep-rooted, prevails in drier areas under natural conditions, and tolerates drouth normally well. In the Jácana soils (profiles 8 and 9) a similar situation was observed with roots extending all the way down to the weathered, somewhat compact parent rock material.

The development of roots of Bermuda grass was apparently limited in profile 17 by the denser layer below the upper two horizons. In profile 6 they went deeper, the soil was much lighter, and there were fewer small pores than in profile 17.

DISCUSSION

The influence of these soil factors upon root development has been recognized by Veihmeyer and Hendrickson (*9,10*) since 1946. They reported critical density values for some loam soils of 1.7 to 1.8, and of 1.6 to 1.7 for clays. In Aiken clay 1.46 gm./cc. was the limiting density. According to Lutz (*5*): "They attribute the failure of roots to penetrate soil above the critical apparent density to the size of the pores and not to the lack of oxygen; roots penetrated saturated noncompacted soils".

In 1956 Lugo-López and Acevedo reported on compaction studies of irrigated soils (*1*). They measured in foot-pounds the work required in sampling 3″ x 3″ soil cores. Significant differences were obtained, the compacted soils requiring much more effort than the loose ones to sample. The same type of resistance values were also reported by Parker and Jenny (*7*) who found that they increased exponentially with increases in core weight. Lutz (*5*) stated: "The values give an indirect estimation of the relative amounts of work done by roots in penetrating tight soils".

Studies to improve genetically compact soils have been conducted locally

TABLE 1.—*Bulk density and volume of small pores of selected soils as related to rooting depth of Para, Guinea, and Bermuda grasses*

Vegetation	Soil series	Soil profile identification No.	Depth	Bulk density	Volume of pores with water at pF 1.78	Observations on root development
			Inches	*Gm./cc.*	*Percent*	
Para grass (*Panicum purpurascens*)	Aguirre	2	0–3	0.88	58.2	Abundant fibrous roots in upper 3 inches, decreasing down to 36 inches, with few roots as far down as 53 inches.
			3–12	1.00	60.0	
			12–32	1.17	78.0	
			38–47	1.10	73.6	
			47–70	1.08	71.3	
Do.	do.	19	0–9	1.22	63.4	Abundant in upper 9 inches with only a few roots extending through the 2 layers below.
			9–19	1.43	68.0	
			19–28	1.40	77.6	
			28–46	1.26	84.8	
			46–66	1.26	78.6	
Guinea grass (*P. maximum*)	Fraternidad	18	0–9	1.15	60.3	Very abundant in upper 9 inches, abundant down to 21 inches, with a large amount of fine roots extending to 44 inches but following cracks and cleavage planes; some roots penetrated easily to lower depths.
			9–21	1.23	66.9	
			21–29	1.39	72.3	
			29–40	1.33	71.9	
			40–44	1.35	67.5	
			44–70	1.39	63.5	
Do.	Jácana	8	0–9	1.36	64.0	Abundant in upper 9 inches, but extending all the way to the weathered parent material at 43 inches.
			9–23	1.33	64.6	
			23–41	1.28	64.1	
			41+	1.64	64.9	
	do.	9	0–10	1.24	64.8	Abundant in upper 10 inches with some extending all the way down to the weathered rock material.
			10–24	1.13	64.5	
			24–29	1.27	65.8	
			29–38	1.46	56.2	
			38+	—	—	
Bermuda grass (*Cynodon Dactylon*)	Fe	17	0–6	1.36	68.9	Most roots confined to upper 6-inch layer; some extended to 14 inches; only very few down to 64 inches.
			6–14	1.35	70.6	
			14–24	1.46	74.2	
			24–33	1.63	74.8	
			33–46	1.60	75.7	
			46–64	1.54	74.7	
Do.	Guánica	6	0–9	1.04	61.5	Abundant down to 45 inches; only a few as far as 72 inches.
			9–18	1.02	59.9	
			18–33	1.01	63.2	
			33–45	1.07	65.2	
			45–60	1.15	65.8	
			60–72	1.14	67.6	

(*6*). The infiltration capacity of a tight soil was increased tenfold by ordinary plowing and harrowing only. Digging down around the borders of the wetted area disclosed that most of the water entering the soil of the plowed and harrowed plots through the immediate surface moved laterally after reaching the claypan. Where the claypan was shattered by the subsoil standard the water moved downward through the disturbed layer.

In general, root development in uncultivated pasture grasses of the types studied seems to respond to the combined variations in bulk density and pore size. Careful recognition must be given the specific genetic differences of the plants.

SUMMARY

Measurements of pore size and bulk density for seven clay soils are reported in this paper as related to observations on root development under field conditions of Para, Guinea, and Bermuda grasses. The combined effects of high bulk density and predominantly small pores apparently reduce root development in Para and Bermuda. Guinea grass, a dryland forage, is able to send roots through relatively dense soil horizons with high microporosity. This might explain, at least in part, the drought tolerance of this grass.

RESUMEN

Se informan aquí medidas de la porosidad y la densidad aparente de siete suelos arcillosos y se relacionan estos con observaciones en cuanto al desarrollo de raíces, bajo condiciones de campo, de malojillo, yerba de Guinea y yerba Bermuda. El efecto combinado de alta densidad y volumen mayor de poros pequeños aparentemente reduce el desarrollo de raíces del malojillo y la Bermuda. Las raíces de la yerba de Guinea, un forraje de zonas áridas, pueden penetrar a través de horizontes densos, donde predominan los poros pequeños. Esto puede explicar en parte la resistencia de esta yerba a condiciones de sequía.

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